first-price sealed-bid when risk averse bidders are present.

Risk aversion is likely to be an important determinant of the winning bid when: (1) the item being sold is very valuable or, more generally, where bids are large relative to any one bidder's assets,[70] and (2) in a multiple-unit setting, the number of items auctioned is small relative to the number of bidders. Each of these sources of risk aversion is likely to play a role in the PCS auction.

Small businesses and many businesses owned by women and minorities could experience the effects of a high bid-to-asset ratio when competing for a given block of spectrum, simply because of a low asset base.[71] A high bid-to-asset ratio can also occur simply because the license may be very valuable. For example, for bidders in a given asset class, the more densely populated and affluent the geographic area, the more valuable the PCS license will be, and the more likely is risk aversion. Similarly, because MTAs are larger than BTAs, we expect them to

---

70 McAfee & McMillan, Auctions, at 726. The authors note examples of such valuable items, including artwork, government contracts, and mineral rights.

71 Recall that, in a private values setting, an optimal bid increases with the number of bidders. In thin markets, auction prices may be far from the highest valuation whether or not there is risk aversion in the bidding population. As noted previously, auction markets for set-aside licenses may be thin. Note, however, that a reserve price could induce risk averse bidders to bid above risk-neutral predictions, even in thin markets.

be more valuable relative to a given firm's assets.

If we were to sort licenses into valuation classes, there would probably be more licenses in relatively low valuation classes than in high classes. That is, while there are relatively few markets with PCS demand characteristics like New York, there may be many like, for instance, Laramie, Wyoming. Bidders are likely to exhibit risk aversion in bidding for licenses in these high-demand markets, while exhibiting less risk aversion in bidding for PCS licenses in low-demand markets.

In sum, it is clear that risk aversion could play a role in PCS auctions. Because the highest valuation bidder obtains the license in the English auction, risk aversion provides the Commission another reason to favor the English auction over a first-price sealed-bid. As McAfee and McMillan note, "when the seller is the government, this [result] provides a reason for using English auctions that is distinct from issues of revenue raising."[72] An English auction would also minimize the number of post-auction transactions.[73]

---

72 McAfee & McMillan, Auctions, at 728.

73 In an empirical analysis of timber-rights auctions, resales occurred only after sealed-bid auctions, and never after an English auction. See R. Johnson, Oral Auction Versus Sealed Bids: An Empirical Investigation, 19(2) Natural Res. J. 315-35 (1979).

VIII. Bidding Complexity

To be successful, each bidder must adopt a rational bidding strategy. In addition to determining its value for the auctioned item, each bidder must consider how rival bidders will bid. The challenge each bidder faces in developing its bidding strategy, moreover, depends upon the form of the auction.

For example, in a first-price sealed-bid auction, each bidder must consider the trade-off between bidding too little and losing the auction against bidding too much and reducing the surplus it earns from the auctioned item. The complexity associated with bidding in a first-price sealed-bid auction is markedly increased when multiple units are offered at auction. For instance, in the PCS auction, each bidder must determine whether it should bid for more licenses than it could efficiently use given the high probability that it will not win every auction in which it submits a bid. Similarly, in making such a determination, each bidder must consider the cost associated with winning PCS licenses that are close substitutes for licenses it has also won.

An oral auction, or its technological cousin, an electronic iterative auction, creates a relatively simple bidding environment for each bidder. In contrast to a sealed-bid auction, an oral auction may better induce bidders to reveal to other bidders their willingness-to-pay for the auctioned item.

In such an auction, each bidder is able to observe its rival's bid and, in so doing, can easily decide how high to bid. Therefore, an oral auction has fewer strategic elements to it than a first-price sealed-bid auction. Because of this advantage, an oral auction will likely be more economically efficient than a first-price sealed-bid auction.

IX. The Commission's Auction Proposal

The Commission has proposed using a two-or-three-step auction procedure in assigning PCS licenses. In the first step, bidders would submit sealed bids for PCS licenses applicable to groups of licenses.[74] Prior to announcing the outcome of this auction, the Commission intends to conduct a sequential, oral auction for awarding individual PCS licenses. The Commission then proposes to award PCS licenses to the winner of the sealed-bid auction for the group of licenses if its bid exceeds the sum of the highest bids submitted in the oral, sequential auction for the individual licenses.[75] The Commission also asks for comment on a variation that would permit the winners in the first round to raise their bids by submitting a sealed "final and best"

---

[74] Notice, para. 51. Currently, it is not clear whether the Commission is proposing a first-price or a second-price sealed-bid auction, although the Notice expresses skepticism about second-price, sealed-bid auctions. See id. para. 45.

[75] The Commission also specifically seeks comment on whether to use combinatorial bidding to allow the aggregation of 10 MHz PCS licenses into 20 MHz or 30 MHz blocks in order to facilitate the provision of nationwide service. Notice, para. 57.

offer.[76]

A. <u>Analysis: The Proposed "Combinatorial Auction"</u>

The Commission recognizes that in order for PCS licenses to be awarded to those bidders that place the highest value on them, the PCS auction must be able to accommodate the geographic and spectrum value interdependencies among PCS licenses.[77] As noted earlier, the combinatorial and contingent bidding auction forms are two methods for capturing these interdependencies. In a combinatorial PCS auction, bidders submit bids for one or more combinations of PCS licenses in different geographic areas or different PCS licenses within a given geographic area.[78] In a well-designed combinatorial auction, bidders should be able to express their demands for any collection of PCS licenses in different geographic areas. Under this requirement, bidders reveal the "true" demand structure for PCS licenses. Moreover, this requirement ensures that the combinations of PCS licenses

---

76 <u>See</u> Notice paras. 60, 120. The number of bidders may be small for some PCS licenses. In this case, the Commission proposes to use a sealed-bid, rather than an oral, sequential auction to assign PCS licenses for BTAs. <u>See</u> Notice, at para. 49.

77 <u>See</u> Notice, para. 52.

78 Because the Commission has proposed a "combinatorial auction," our analysis will focus on this method of capturing PCS value interdependencies. Moreover, our analysis focuses on combining PCS licenses located in different geographic areas. This analysis also applies to the Commission's proposal to permit bidders to offer bids for different spectrum licenses within a given geographic area.

bid upon are the product of marketplace forces, not administrative fiat. As importantly, all the information regarding the demand for PCS licenses (i.e., bids) should be presented to the seller in a simultaneous fashion. This feature ensures that the seller has all the information it needs to determine the efficient allocation of PCS licenses.

The Commission's proposed combinatorial auction does not satisfy these requirements. For instance, the proposed auction would allow participants to bid on only one geographic combination of PCS licenses for each of the two proposed 30 MHz licenses -- the nationwide set of 51 MTAs. This combination of PCS licenses was determined, not by the offers submitted by bidders, but by the Commission.[79] Moreover, the Commission proposes to order PCS licenses according to geographic area and auction them off in succession. Such a "sequential auction" does not allow the seller to consider all the information concerning PCS demand prior to making any assignment decisions. Indeed, because the bidder that places the highest valuation on a group of PCS licenses does not necessarily win every individual, sequential PCS auction, the proposed auction will likely assign some PCS licenses to bidders that do not value them most highly (i.e., the auction will be economically inefficient). Because it does not satisfy these requirements, the Commission's proposed

---

[79] The Commission also requests comments on whether combinatorial bidding should be used to facilitate grouping of BTA licenses into MTAs. Notice, para. 123.

auction will be economically inefficient.

1. <u>An Example Based on the Commission's Proposal</u>

The problems with the proposed auction form can be demonstrated with the aid of a simple example. Let a geographic area consist of a single MTA, which is comprised of three BTAs. Suppose a single PCS license is associated with each BTA. Further, suppose that the PCS licenses associated with the BTAs are assigned through a simultaneous oral auction, while the PCS license for the MTA is assigned through a sealed-bid auction.[80] Finally, suppose PCS licenses are assigned to the winners of the BTA auctions only if the sum of their individual bids exceeds the winning bid in the MTA PCS auction. Like the Commission's proposal, this assignment rule ignores bids submitted for combinations of PCS licenses smaller than the MTA. Table 1 lists hypothetical valuations of three bidders for each PCS license and the combination of all such licenses.

---

[80] This example assumes that a simultaneous oral auction is used to assign BTA licenses. However, as discussed earlier, a sequential auction is inferior to a simultaneous auction in this instance. Therefore, our example may understate the difficulties with the Commission's proposal. We have further simplified our analysis by assuming that the four "revenue equivalence" conditions hold. <u>See</u> McAfee & McMillan, <u>Auctions</u>, at 706. Under these conditions, an oral auction and a first-price sealed-bid auction will yield the same revenue to the seller. We note, however, that the revenue equivalence conditions have been proven only for single-unit auctions.

Bidder	BTA_1	BTA_2	BTA_3	BTA_{123}=MTA
#1	60	30	30	140
#2	30	60	20	130
#3	40	75	20	135

Table 1: HYPOTHETICAL VALUATIONS

The "optimal" allocation of PCS licenses under these rules is derived by comparing the sum of the values that individual BTA winners place on their PCS licenses with the value the winning bidder places on its MTA license. Bidder #1, the winner of the MTA auction, places a value of 140 on its license, while the sum of the values individual BTA winners place on their licenses is 165. Therefore, the optimal allocation, from an efficiency standpoint, has Bidder #1 obtaining licenses one and three, while Bidder #3 obtains license two.

However, the seller assigns PCS licenses based not on the winner's total value, but according to earned revenue. In an oral auction, Bidder #1 wins licenses one and three at prices of 40 and 20, respectively, while Bidder #3 wins license two at a price of 60.[81] Therefore, the seller earns 120 in revenue if it assigns its PCS licenses to these winners. On the other hand,

[81] The theoretical literature states that, in an oral ascending auction, the highest valuation bidder will pay a price approximately equal to the bid submitted by the second highest valuation bidder.

the seller would receive 135 for all three PCS licenses from Bidder #1. The seller, therefore, would award all three licenses to Bidder #1 even though total value is maximized if Bidder #1 obtains two PCS licenses and Bidder #3 receives one. The auction rules have led to an economically inefficient assignment of PCS licenses. Moreover, such rules will not maximize revenue since the misallocation of PCS licenses will cause an after-assignment transaction between Bidders #1 and #3. This transaction will occur because Bidder #1 places a value of 40 on BTA2 (i.e., 140-100 or Bidder #1's MTA value minus its BTA13 value, see Table 2), while Bidder #3 places a value of 75 on such a license.[82]

The auction can be modified in two ways in order to substantially reduce the likelihood of this inefficiency, as well as to increase seller revenue. First, the auction must allow for bidding on additional combinations of PCS licenses. Second, during the bidding process parties should be allowed to coordinate to raise their bids in order to increase their respective welfares. We explain these two modifications below.

To demonstrate the effects of bidding for additional combinations, Table 2 lists hypothetical valuations submitted by three bidders for all the different geographic combinations of

---

[82] See Table 2 below for Bidder #1's BTA13 value.

these PCS licenses.[83] According to Table 2, the seller would

Bidder	BTA_1	BTA_2	BTA_3	BTA_{12}	BTA_{13}	BTA_{23}	BTA_{123}=MTA
#1	60	30	30	100	100	60	140
#2	30	60	20	90	70	80	130
#3	40	75	20	115	60	95	135

Table 2: HYPOTHETICAL VALUATIONS: MORE COMBINATIONS

earn 135 if it were to assign all three licenses to Bidder #1, and would earn 130 if it assigned licenses one and three to Bidder #1 and license two to Bidder #3. Because the seller earns more from selling all three of its PCS licenses to Bidder #1 than from any other assignment, it will still sell them to Bidder #1.[84] Moreover, this allocation is still sub-optimal. Bidder #1, the winner of the combinatorial auction, places a value of 140 on its MTA license, while the sum of the values individual BTA winners place on their licenses is 175.[85]

---

83 In addition to including Table 1's entries, Table 2 includes a listing of bids for combinations of PCS licenses smaller than the MTA.

84 The revenue the seller would earn from assigning its PCS licenses to Bidders #1 and #3 has increased by 10 (i.e., 130-120).

85 Allowing bidders to bid on all combinations of PCS licenses has revealed the "true" cost of assigning all three PCS licenses to Bidder #1. Without this flexibility, there is an inefficiency of 25 (i.e., 165-140). With this flexibility, there is an inefficiency of 35 (i.e., 175-140).

While in this instance allowing bidders to bid for all different combinations of PCS licenses has not resulted in the optimal assignment of such licenses, in other instances it will. For instance, the optimal assignment could have been achieved if, in this example, the second highest bid for license two was 70 rather than 60.[86] More generally, the smaller the variance (i.e., less dispersion) in bidder valuations for PCS licenses, the greater the likelihood that PCS licenses will be assigned in an economically efficient manner.

Second, the likelihood of an economically inefficient outcome would have been reduced further if either Bidder #1, Bidder #3, or both volunteered to increase their bids in order to enhance, relative to the status quo, their respective welfares. The difficulties Bidders #1 and #3 may have in making such contributions can be described in terms of "game theory".[87] The status quo has Bidder #1 obtaining all three licenses, which it values at 140, for a price of 135. However, if Bidder #3

---

86 Similarly, the optimal assignment would have occurred if the second highest valuation for licenses one and three, taken together, was 80 rather than 70.

87 Game theory is a tool by which one can analyze the strategic interaction between "players" (e.g., individuals, firms, governments). A "game" occurs whenever two or more players find themselves in a situation in which each must choose a strategy from a set of alternatives, and in which each player's welfare depends upon the strategies adopted by the other players. Game theory attempts to identify each player's "best" strategy given its objectives (e.g., market share, profits, trade surplus). See Myerson, Game Theory (1991).

obtained license two, the optimal assignment of PCS licenses would be achieved and seller revenue could increase. As previously noted, Bidder #1's bid on BTA13 is 70 and Bidder #3's BTA2 bid is 60 (see Table 2). The sum of these bids is only 130, not enough to defeat Bidder #1's bid of 135 for all three licenses. Any increase in the sum of these bids greater than 5 would achieve the optimal assignment and increase seller revenue. Moreover, if either Bidder #1 or Bidder #3 increased its bid by 5.01, it could increase its "payoff" -- the difference between the value of the licenses it wins and its winning bids.

The issue for the seller is how to provide a mechanism for bidders to raise their bids to reach this desirable result. Permitting cooperation or coordination among bidders is one way to do so. In our example, suppose that each bidder must decide whether to increase its bid by 5.01. The possible outcomes or payoffs of any pair of strategies are shown in Table 3. An "I" represents an increase in the initial bid, while an "N" indicates no increase in the initial bid. The columns of this matrix represent the decisions by Bidder #3, while the rows indicate the decision adopted by Bidder #1. The numbers in each cell of this matrix represent the payoff each bidder will receive as a result of each pair of strategies. The lower left number represents Bidder #1's payoff, while the upper right number represents

Bidder #3's payoff.

		Bidder #3	
		I	N
Bidder #1	I	9.99 24.99	15 24.99
	N	9.99 30	0 5

Figure 2: COORDINATION PAYOFF MATRIX

If neither bidder increases its bid, the status quo obtains -- Bidder #1 obtains all three licenses and receives a payoff of 5 (<u>i.e.</u>, v(MTA)-(MTA Bid)=140-135), while Bidder #3 obtains nothing and receives no payoff (lower right-hand cell). Note that both Bidder #1 and #3 can improve their welfare if Bidder #3 obtains license two through the auction process. However, myopic self-interest may prevent this outcome from occurring. For instance, if Bidder #1 increases its BTA13 bid by 5.01 while Bidder #3 stands pat, Bidder #1's payoff increases to 24.99 (<u>i.e.</u>, its valuation for licenses one and three (100), less its previous bid (70), less its contribution of 5.01), while Bidder #3's payoff increases from zero to 15 (<u>i.e.</u>, its valuation for license two (75), less its previous bid (60)). On the other hand, if Bidder #3 increases its bid by 5.01, and Bidder #1 stands pat, Bidder #3 receives 9.99 (<u>i.e.</u>, v(BTA2)-(Initial Bid)-

(Bid increase)= 75-60-5.01) while Bidder #1 receives 30 (i.e., its valuation for licenses one and three (100), less its previous bid (70)). Therefore, each bidder is better off not increasing its bid when the other bidder increases its bid. In this situation, neither bidder wants to be the one to increase its bid. Instead, each prefers to "free-ride" off of the other's bid increase.[88]

Each bidder, however, also has the incentive to cooperate because the payoffs associated with all the other pairs of strategies dominate the payoffs associated with the status quo (i.e., no cooperation). For instance, if Bidders #1 and #3 both increase their bids by 5.01, Bidder #3's payoff increases from zero to 9.99 while Bidder #1's payoff increases from 5 to 24.99. Moreover, as shown in Table 3, even if one bidder increased its bid, and the other bidder did not, the cooperating bidder receives a larger payoff than if it did not act cooperatively. Whether cooperation will occur in the PCS auction environment depends on the extent to which each bidder wishes to free ride and on the ability of each bidder to reveal to other bidders its willingness to cooperate.

---

[88] The possibility of an inefficient outcome due to the free-rider problem is significant in the Commission's proposed auction. For instance, a national license may be awarded for blocks A and B because of the difficulty that high bidders for MTAs may have in coordinating their individual bids.

To help solve this free-rider problem, the Commission should provide these high valuation bidders a mechanism by which they can arrive at a cooperative agreement.[89] One such mechanism involves allowing bidders to propose to other bidders a method for increasing the sum of their individual bids. This includes identifying how much each high valuation bidder should increase its bid. In the previous example, Bidder #1 could have suggested to Bidder #3 that they both increase their bids by 2.505. Such bidders must be allowed some time to respond to such an offer. A response may be in the form of an acceptance or a counteroffer.[90] An acceptance would maximize economic efficiency and increase seller revenues over the status quo.

---

[89] As the Commission correctly observes, unless bidders can work out a solution, the free-rider problem may prevent PCS licenses from being awarded to those bidders that value them most highly. However, the Commission is mistaken in believing that a Vickrey auction would solve this problem. See Notice, para. 62. Indeed, our example's results would not have changed, assuming the revenue neutrality conditions hold, had we employed a Vickrey rather than an oral auction. Moreover, the Commission has proposed not to reveal to bidders in the oral auction the value of the highest sealed-bids. Such bidders will, therefore, not even know whether the sum of their individual bids exceeds the highest sealed-bid for the group license. This feature of the Commission's auction increases the likelihood of a free-rider problem and, thus, an inefficient outcome.

[90] In practice, the highest bidder for group licenses should have an opportunity to respond to this new, higher price offered by these bidders.

2. Sequential Auction Issues

As we have stated, the Commission's proposal uses a sequential oral auction to award PCS licenses associated with individual BTAs or MTAs. Such an auction is a poor instrument for capturing the geographic and spectrum-related interdependencies in the value bidders place on PCS licenses. Consider again the valuations presented in Table 2. In this table, the value of some collections of PCS licenses is greater than the sum of their individual values. In a sequential auction, each bidder may have to decide when to reveal, in the form of a higher bid, these potential "synergies". Suppose each bidder reasons that because it can only realize these synergies if it obtains all of the licenses in the group, it should be willing to reveal all potential synergies in the earliest auction.[91] This strategy is tantamount to a bidder asking itself, "Assuming that I win all subsequent auctions for items which I value interdependently, what is the most I would be willing to pay for the license being auctioned presently?"[92]

In our example, assume that license one is auctioned first followed by licenses two and three. If each bidder is willing to reveal its entire synergy valuation in the initial auction, it

---

91 This example also assumes that each bidder believes that it would be more costly to acquire PCS licenses in an after-assignment transaction than in the auction.

92 We realize this is an aggressive strategy, but similar results can be derived assuming less aggressive bidding strategies.

should compute its valuation for license one by subtracting its valuations for individual licenses two and three from its valuation for all three licenses (i.e., v(BTA1) = v(MTA - (BTA2 + BTA3))). Such a calculation results in valuations of 80, 50 and 40 for Bidders #1, #2, and #3, respectively. In an oral auction, therefore, Bidder #1 obtains license one at a price of 50.

In the next auction, for license two, Bidder #1 computes its valuation in the same way it did for license one. That is, it subtracts its valuations for individual licenses one and three from its valuation for all three licenses (i.e., v(BTA2) = v(MTA - (BTA1 + BTA3))). Bidders #2 and #3, however, cannot reap all the benefits from holding all three licenses because of their loss in the initial auction. Each computes its value for license two by subtracting its stand-alone valuation for license three from its joint valuation for licenses two and three (i.e., v(BTA2) = v(BTA23 - BTA3)). The resulting values are 50, 60, and 75 for Bidders #1, #2, and #3, respectively. Bidder #3, therefore, wins the auction for license two at a price of 60.

In the final auction, for license 3, Bidder #1 can no longer obtain all three licenses and so computes its value by subtracting its stand-alone valuation for license one from its joint valuation for licenses one and three (i.e., v(BTA3) = v(BTA13 - BTA1)). Bidder #2, a loser in both of the previous auctions, has only its stand-alone value for license 3. Bidder

#3, who won license two, computes its value by subtracting its stand-alone valuation for license two from its joint valuation for licenses two and three (i.e., v(BTA3) = v(BTA23 - BTA2)). The resulting values are 40, 20, and 20 for Bidders #1, #2, and #3, respectively. Bidder #1 wins the auction and pays a price of 20.

Notice that the resulting allocation -- Bidder #1 owns licenses one and three, Bidder #3 owns license two -- is economically efficient. That is, the allocation achieves the highest possible total valuation (i.e., 175). However, in achieving this allocation the seller received total payment of only 130, which is below what it could have obtained if combinatorial bidding had been permitted. From the seller's perspective, the sequential auction was a poor way to capture value interdependencies among PCS licenses.

Importantly, these results are sensitive to the order in which the seller auctions the licenses. Assume, for example, that the seller offers license one last instead of first.[93] In the first auction, bidders compute their valuations for license 2 in the same way as they did in the initial round in the previous example (i.e., v(BTA2) = v(MTA - (BTA1 + BTA3)). The resulting valuations are 50, 80, and 75 for Bidders #1, #2, and #3,

93 In this example, licenses are auctioned according to the sequence: license two, license three, and license one.

respectively. Bidder #2 wins the auction at a price of 75. This price is 15 over Bidder #2's valuation of license two on a stand-alone basis (i.e., 75-60). This difference of 15 represents part of Bidder #2's valuation of the synergy it could potentially realize after first winning license two.

In the next auction, Bidders #1 and #3, losers in the first auction, compute their valuations for license three by subtracting their values for license one from their joint valuations for licenses one and three. Bidder #2, the winner in the auction for license two, computes its value by first subtracting its stand-alone valuations for licenses one and two from its joint valuation for all three licenses. Bidder #2, however, "spent" some of its synergy valuation in the previous auction. To derive the appropriate valuation for license three, this spent valuation must also be subtracted from its joint valuation for all three licenses (i.e., v(BTA3) = v(MTA - (BTA1 + BTA2 + spent synergy))). The resulting valuations for Bidders #1, #2, #3 are 40, 25, and 20 respectively, and Bidder #1 wins the auction at a price of 25.

In the final auction, Bidders #1 and #2 compute valuations for license one by subtracting their stand-alone values for the licenses they have won from their joint valuation for these licenses plus license one. Bidder #3, who has won no licenses, enters the auction with its stand-alone valuation for license one. The resulting valuations are 70, 30 and 40 for Bidders #1, #2, and #3, respectively. Bidder #1 wins the auction and pays a price of 40.

Because Bidder #3 did not obtain license two, the final allocation is sub-optimal, achieving a total valuation of only 160. Interestingly, total revenues are now 140. However, Bidder #2 has paid 75 for a license it only values at 60. If post-auction transactions are permitted, Bidder #2 will minimize its losses by selling license two to Bidder #3 for some price between 60 and 75. In this case, the sequential auction performs well in terms of revenue, but poorly in terms of efficiency.

In the previous example, Bidder #2 harmed itself by bidding too aggressively in the first auction. Bidder #2 was, however, in a difficult situation -- revealing its synergy valuation early in the auction left few resources for later auctions, but not revealing that valuation would have meant no chance of obtaining the multiple licenses necessary to achieve these synergies. In general, when bidders have no information about their opponents' valuations in subsequent auctions, how to reveal synergy valuations optimally is a difficult task -- so difficult that the resulting allocation may be inefficient. Therefore, when bidders have strong value interdependencies on items, a simple sequential auction mechanism will likely be inferior to the simultaneous combinatorial mechanism. Indeed, a sequential auction may hinder, rather than assist, the seller in capturing some of the surpluses associated with owning geographically adjacent PCS licenses.

The inferiority of the sequential versus the simultaneous auction in capturing PCS license interdependencies is not offset by other performance characteristics. Although, in a sequential auction, the bids submitted in early auctions may convey information on the true value of the items to be sold in later auctions, this information will not necessarily help increase either efficiency or auction revenues.[94] For example, if a bidder knows that its bid could reveal information about the expected selling price of a PCS license to be auctioned later, it has an incentive to underbid. While this deception may lower the bidder's chances of winning the first PCS license, the bidder may stand to gain in later auctions.[95]

In addition, the usefulness of the information obtained from early auctions regarding the likely value of subsequently

---

[94] See D. Hausch, Multi-object Auctions: Sequential vs. Simultaneous Sales, 32 Mgmt. Science 1599-1610 (1986).

[95] The extent to which a bidder will underbid depends, in part, on the potential costs and benefits of making such a bid. The existence of synergies related to owning a collection of adjacent PCS licenses increases the potential cost of underbidding for any individual license in that group. Therefore, assuming that each bidder believes that it would be more expensive to acquire a PCS license in an after-assignment transaction than in the auction, the incentive to underbid in early auctions will be offset somewhat by the presence of these synergies.

auctioned PCS licenses depends upon the uniformity of the PCS licenses. As discussed earlier, spectrum licenses are largely heterogeneous goods. Such non-uniformity reduces significantly the information value of earlier PCS auction outcomes. The usefulness of information derived from earlier auctions depends upon whether the auction will occur in a private versus common value setting. For instance, bidders would find such information much more useful in a common value setting than in a private value setting. As discussed earlier, we believe that the PCS auction will occur primarily in a private value setting.

In summary, the Commission's proposed "combinatorial auction" has some significant problems.[96] It is not firmly grounded in theoretical or empirical analysis. It will be relatively economically inefficient. Because it fails to elicit from each bidder the valuations it places on different bundles of PCS licenses, there exists a strong possibility that the Commission's auction form will award PCS licenses to the "wrong" bidder -- that is, a bidder whose valuation for a particular PCS license is not the highest. Because of this, use of the proposed auction form could result in numerous after-assignment transactions between the PCS license winners and entities that

---

[96] However, the Commission is correct in its assessment that a combinatorial auction is needed to assign PCS licenses. Without such an auction, such licenses will not be assigned to bidders that value them most highly and will also likely have relatively poor revenue generating characteristics.

value PCS licenses more highly. The costs of transferring these licenses to such entities measure the magnitude of the auction's economic inefficiency. Finally, the Commission's proposed auction has relatively poor revenue generating characteristics. As indicated by our analysis, a sequential auction in the PCS auction context will not capture the surpluses that licenseholders earn from owning geographically adjacent PCS licenses.

X. Summary and Recommendations

Although there are common value features in the PCS auction, it will occur in what is predominantly a private value setting. In such a setting, inefficient outcomes can result from both bidder asymmetries and risk aversion. As argued above, both asymmetry and risk aversion are likely to be important in these auctions. Because high valuation bidders can react, through an increased bid, to bidding behavior consistent with risk-aversion and bidder asymmetry, the English oral auction is superior to the first-price sealed-bid auction from an efficiency perspective. In English auctions, the bidder that places the highest value on the item wins it, and thus this mechanism is also likely to minimize after-assignment transactions.

Of course, the above preference for the English auction is based on single-unit auction research. PCS auctions will occur in a multiple-unit environment. Because the Commission must assign thousands of PCS licenses within a short period of time, we recommend that it employ a computer to record the bids submitted for PCS licenses and identify the winning bidder. Because of the computer's superior numerical processing capabilities, we believe that an electronic or "computer-assisted" auction could proceed more quickly than a non-electronic auction in determining winning bidders for PCS licenses.

More importantly, however, to promote economic efficiency and to increase revenues, we favor an auction mechanism that enables bidders to fully reveal all of the value interdependencies among PCS licenses. Candidates include both combinatorial and contingent bidding mechanisms. Because of the latter's complex bidding information requirements, we recommend that a combinatorial auction mechanism be chosen. Consistent with allowing bidders to reveal all the demand interdependencies among licenses, we recommend that bidders be allowed to submit "package bids" for any collection of PCS licenses they choose in different geographic areas. Under this "full information" combinatorial approach, bidders will reveal the true demand structure for PCS licenses as dictated by marketplace forces rather than administrative fiat. By allowing bidders to define important features of the auction unit, such an auction would reduce the risk associated with attempting to anticipate the packages of PCS licenses valued most highly in the market.

We also recommend that the PCS auction permit bidders to respond to bids submitted by other bidders. As in a single-unit English auction, this "iterative" feature will enhance the economic efficiency of PCS auctions by reducing the likelihood that licenses will be assigned to entities other than the highest valuation bidders because of either bidder asymmetries or risk-averse bidding. Moreover, we believe that an electronic iterative auction will decrease the difficulties each bidder faces in developing its bidding strategy by providing each bidder with information on how their rivals are bidding. By decreasing such difficulties, such an auction will likely provide a more economically efficient assignment of PCS licenses than a first-price sealed-bid auction.

As the Commission correctly observes, a "free-rider" problem may prevent PCS licenses from being awarded to those individual bidders that value them most highly. In order to limit the economic inefficiencies caused by this problem, we recommend that the Commission design, as part of its auction form, a mechanism that allows high valuation bidders on individual or small groups of licenses to coordinate their bids in an effort to raise their combined bids above the highest combinatorial bid for a larger group of licenses.

In summary, we recommend that the Commission adopt an electronic, iterative, combinatorial auction (EICA). The